Government of Tamil Nadu

Department of Employment and Training

Course : TNPSC Combined Civil Services Examination - IV(Group IV / VAO)

Subject : Physics

Topic : Nature of Universe

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Commissioner,

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NATURE OF UNIVERSE

UNIVERSE

The Universe is commonly defined as the totality of existence, including planets, stars and galaxies, the contents of intergalactic space, and all matter and energy.

The most widely accepted cosmological model is that of the Big Bang. This was proven since the discovery of the cosmic microwave background radiation or CMBR. The Universe was infinitely hot at birth, cooling down as it expanded.

Today's Universe is found to have an average temperature of only 2.725 Kelvin. Observations made especially on galaxies farthest from us show that the Universe is expanding at an accelerated rate.

The Universe mainly consists of Galaxies, Stars, Solar System, Comets, Meteors and Asteroids.

Galaxy

A galaxy is a collection of stars, dust and gas. All these materials bound together gravitationally to form a galaxy. Gas and dust found in galaxy in between the stars. It is called interstellar gas, which is mainly hydrogen in its atomic form (H) and to some extent, in molecular form (H2).

Gas forms an important constituent of Galaxy.

Stars are the third and final constituents of galaxies. Number of stars in a galaxy ranges from 10 million to more than a trillion.

Our sun is in a galaxy called the Milky Way that contains more than 100 billion stars. There are more than 100 billion galaxies in the universe, and the average number of stars per galaxy may be 100 billion.

Star

A star is a huge, shining ball that produces a large amount of energy in form of light and other forms.

Stars are very far from us, that's why they look like twinkling points of light. Our sun is also a star. A lot of stars are like our sun. Some differ in mass, size, brightness and temperature.

The nearest star to the Earth is Sun. It is nearly 150000000 kilometers away from the Earth.

The next nearest star is Alpha Centauri. It is at a distance of about 4×10^{13} km from the Earth.

Constellation

The stars forming a group that has a recognizable shape is called a Constellation.

For example, one can see Ursa Major during summer time in the early part of the night. It is also known as the Big Dipper, the Great Bear or the Saptarshi.

Another well known constellation, Orion can be seen during winter in the late evenings. It is also called the Hunter.

Stars come in many sizes. Some of the stars have a radius of about 1,000 times that of the sun.

The smallest stars are the neutron stars, some of which have a radius of only about 6 miles (10 kilometers).

Stars have life cycles. They born, pass through several phases, and finally die. Some will not go through a red giant stage. Instead, they will merely cool to become white dwarfs, then black dwarfs. A small percentage of stars will die in spectacular explosions called supernovae.

Brightness of star seen from Earth depends on two factors:

- The amount of light energy the star emits.
- The distance from Earth to the star.

SURFACE TEMPERATURE

The surface temperature of a star is determined by the rate of energy production at the core and the radius of the star.

The temperature in the core region of a star is several million kelvin. The surface temperature of a star, along with its visual absolute magnitude and absorption features, is used to classify a star.

Why stars are of different colors?

Color of star is the color of light the star is emitting. A star can appear red, if it emits light more towards red part of visible band of electromagnetic spectrum, and can appear blue if it emits light more towards blue part of visible spectrum.

Our sun emits light equally among all wavelengths of visible spectrum. That is why our sun appears white to us. Color of the star depends on its surface temperature.

ASTEROIDS

Asteroids are small rocky bodies that orbit the sun in a belt (Kuiper belt) between orbits of Mars and Jupiter.

Not all the asteroids orbit in Kuiper belt. Some are between orbit of Jupiter and some are beyond the orbit of Saturn.

Earth has been struck many times by an asteroid.

METEORS

A meteor is a bright streak of light that appears briefly in the sky.

Meteors are often called shooting stars or falling stars because they look like stars falling from the sky.

Brightest meteors are sometimes called fireballs. A meteor appears when a particle or chunk of metallic or stony matter called a meteoroid enters the earth's atmosphere from outer space.

Air friction heats the meteoroid so that it glows and creates a shining trail of gases and melted meteoroid particles.

Most meteoroids disintegrate before reaching the earth. But some leave a trail that lasts several minutes. Meteoroids that reach the earth are called **meteorites.**

COMETS

Comets revolve around the Sun in highly elliptical orbits. However, their period of revolution around the Sun is usually very long. A Comet appears generally as a bright head with a long tail.

The length of the tail grows in size as it approaches the Sun. The tail of a comet is always **directed away from the Sun**.

Many comets are known to appear periodically. One such comet is Halley's Comet, which appears after nearly every 76 years.

THE SOLAR SYSTEM

The Sun and the celestial bodies which revolve around it form the solar system. It consists of large number of bodies such as planets, comets, asteroids and meteors.

The gravitational attraction between the Sun and these objects keeps them revolving around it.

The earth is planet and a member of the solar system.

There are seven other planets that revolve around the Sun.

The eight planets in their order of distance from the Sun are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune.

Till 2006 there were nine planets in the solar system.

Pluto was the farthest planet from the Sun.

In 2006, the International Astronomical Union (IAU) adopted a new definition of a planet.

Pluto does not fit this definition. It is no longer a planet of the Solar System.

A planet has a definite path in which it revolves around the Sun. This path is called an Orbit.

MERCURY

The planet Mercury is nearest to the Sun.

It is the smallest planet of our solar system.

Mercury has no satellite of its own.

VENUS

Venus is earths nearest planetary neighbour.

It is the brightest planet in the night sky.

Sometimes it appears in the eastern sky before sunrise.

Sometimes it appears in the western sky just after Sunset.

Therefore, it is called a morning or an evening star.

Venus has no moon or satellite of its own.

It rotates from east to west while the Earth rotates from west to east.

EARTH

The Earth is the only planet in the solar system on which life is known to exist.

Some special environmental conditions are responsible for the existence and continuation of life on the Earth.

From space, the Earth appears blue-green due to the reflection of light from water and landmass on its surface.

The axis of rotation of the Earth is not perpendicular to the plane of its orbit.

The tilt is responsible for the change of seasons on the Earth.

The Earth has only one moon.

MARS

The next planet, the first outside the orbit of the Earth is Mars.

It appears slightly reddish and therefore it is also called the red planet.

Mars has two small natural satellites.

JUPITER

Jupiter is the largest planet of the solar system.

It is so large that about 1300 earths can be placed inside this giant planet.

But, the mass of Jupiter is about 318 times that of our Earth.

SATURN

Beyond Jupiter is Saturn which appears yellowish in colour.

It is the least dense among all the planets.

Its density is less than that of water.

Its beautiful rings make it unique in the solar system.

URANUS AND NEPTUNE

These are the outermost planets of the solar system.

Like Venus, Uranus also rotates from east to west.

The most remarkable feature of Uranus is that it has highly tilted rotational axis.

BLACK HOLE

Is a region of spacetime from which gravity prevents anything, including light, from escaping.

The theory of general relativity predicts that a sufficiently compact mass will deform spacetime to form a black hole.

Around a black hole there is a mathematically defined surface called an event horizon that marks the point of no return.

It is called "black" because it absorbs all the light that hits the horizon, reflecting nothing, just like a perfect black body in thermodynamics.

Black holes of stellar mass are expected to form when very massive stars collapse at the end of their life cycle. After a black hole has formed it can continue to grow by absorbing mass from its surroundings. By absorbing other stars and merging with other black holes, supermassive black holes of millions of solar masses may form.

There is general consensus that supermassive black holes exist in the centers of most galaxies.

Gravitational Force

We are all aware of the force which pulls us towards the earth. This is called gravitational force. In fact the gravitational force exists between all bodies, even between two apples lying on a

table.

It is gravitational force that holds the moon in its orbit round the earth and the earth in its orbit round the sun.

Newton's Law of Universal Gravitation

Newton's Law of Universal Gravitation states that every particle in the universe attracts every other particle with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

In equation form, the gravitational force,

$$F = Gm_1m_2 / r^2$$

where r is the distance between two particles of masses m1 and m2 and G the universal gravitational constant.

The value of G is 6.67×10^{-11} SI units.

Centripetal Force

For a body to move in a circle there must be a force on it directed towards the centre. This is called the centripetal force and is necessary to produce continuous change of direction in a circular motion.

In case of the moon, gravitational force between the earth and the moon acts as the centripetal force.

When a stone tied at one end of a string is whirled in a circle, the pull in the string provides the centripetal force.

The magnitude of the centripetal force, Fc , required to cause an object of mass m and speed v to travel in a circular path of radius r is given by the relation

$$F_c = mv^2 / r$$

Centrifugal Force

This force is supposed to be acting on a body revolving in a circle. Centrifugal force is equal and opposite to centripetal force, i.e., it acts outwards.

It may be emphasised that centrifugal force is not a real force, however it is invoked to explain various phenomena successfully.

Weight

The weight of a body is the force with which the earth attracts the body towards its centre.

The weight of a body should not be confused with its mass, which is a measure of the quantity of matter contained in it.

When we say that a person weighs 60 kg, we are actually describing his mass and not weight. The mass of a body is a constant quantity whereas its weight varies slightly from place to place
on the earth.

The weight of a body is maximum at the poles and minimum at the equator.

This variation in weight is due to:

(i) the shape of the earth and

(ii) the rotation of the earth about its axis.

The earth is not a perfect sphere but bulges at the equator. The equatorial radius is more than the polar radius by about 21.5 km.

Therefore, from Newton's law of gravitation it can be easily seen that gravitational force, and hence the weight of a body at the poles, should be more than that at the equator.

Also, due to the rotation of the earth, a body on the surface of the earth revolves in a circular path and, therefore, a centrifugal force acts on it.

The centrifugal force is zero exactly at the poles and maximum at the equator.

Since the centrifugal force acts outwards, it reduces the effect of the gravitational pull and hence a body weighs minimum at the equator. The weight of an object is also less at high elevations than at sea level.

For example, an object would weigh less in Simla than in Mumbai.

It can also be shown that the weight of an object should be less inside a mine. At the centre of the earth, the weight of a body would be zero.

The weight of a body can also be expressed in terms of the acceleration due to gravity (g). The weight (W) of a body of mass m is given by the product of m and g,

i.e., $W = mg$

It is now obvious that the value of g is maximum at poles and minimum at the equator. At the centre of the earth, g would be zero.

On the surface of the moon the value of the acceleration due to gravity is nearly one-sixth of that on earth and, therefore, an object on the moon would weigh only one-sixth its weight on the earth. (The mass of an object on the moon would, however, be the same as on earth).

It would be interesting to imagine the effect of change in the speed of the earth's rotation on the weight of bodies.

The weight of a body would be more if the earth stopped rotating. Conversely, if the speed of rotation were higher, the weight would be less.

It is not hard to imagine that at a critical speed of rotation of the earth a body would become weightless.

Suppose a person is standing on a weighing scale (of the type which doctors use) in a lift. When the lift is stationary, the scale shows his actual weight. When the lift accelerates upward, the scale shows higher weight because the scale pushes harder against his feet. When the lift accelerates downward, the scale shows less weight. If the cable of the lift breaks and it starts falling freely, the reading on the scale becomes zero and the person experiences weightlessness.

Is the person really weightless? The answer is—no. The earth is still attracting the person but since he and the scale are both falling with the same acceleration, the latter does not push against his feet and therefore shows no weight. Consider an astronaut orbiting the earth in a spaceship. In a loose sense he is in a state of weightlessness. He feels weightless because he is not pushing against anything.

The situation is similar to that in a freely falling lift.

Friction

Friction is the force which opposes the relative motion of two surfaces in contact. Friction plays an important role in our lives.

It is friction between the ground and the soles of our shoes that makes walking possible and it is lack of friction that makes our feet slip on highly polished surfaces.

The force of friction that acts when a body is moving (sliding) on a surface is called sliding friction.

The amount of sliding friction depends on the nature of the two surfaces and not on the area of contact.

However, it also depends on the weight of the moving body. Heavier objects experience more friction.

When a cylindrical or spherical body rolls over a surface, the force opposing the motion is called rolling friction.

For the same pair of materials, rolling friction is much smaller than sliding friction. While friction is necessary in some circumstances, it becomes a nuisance in others.

Friction in machines wastes energy and also causes wear and tear.

This friction is reduced by using (i) lubricants, and (ii) ball bearings.

The presence of a liquid lubricant in a machine prevents metal-to-metal contact and since the friction between liquid layers (called viscosity) is much less than the friction between solids, the frictional forces in the machine are greatly reduced.

Since rolling friction is much less than sliding friction, the use of ball bearings in a machine considerably reduces friction.

When an object moves through air, frictional forces oppose its motion. However, air friction is much less than liquid friction.